

1 **What is claimed is:**

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3 I claim:

4 1. An offshore system for petroleum production, comprising:

5 a buoyant hull;

6 a tendon assembly cooperatively engaged with the hull;

7 a counterweight at a lower end of the tendon assembly to provide tension to the tendon assembly,

8 an anchor member embedded in a sea floor and having an upper end protruding above the sea

9 floor; and

10 an engaging member at the lower end of the tendon assembly that telescopingly engages the

11 upper end of the anchor member to restrict lateral movement of the hull and accommodate heave

12 of the hull.

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14 2. The system according to claim 1, wherein the upper end of the anchor member and the

15 engaging member are tubular.

16

17 3. The system according to claim 1, wherein the upper end of the anchor member and the

18 engaging member define a chamber that varies in volume as the tendon assembly moves up and

19 down due to heave of the hull, the chamber having a port to draw in and expel sea water to

20 dampen the up and down motion of the tendon assembly.

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22 4. The system according to claim 3, further comprising a check valve in the port that provides a

23 greater flow area for the egress of sea water during downward movement of the engaging

1 member than a flow area for the ingress of sea water during upward movement of the engaging
2 member.

3
4 5. The system according to claim 1, wherein the upper end of the anchor member and the
5 engaging member define a chamber that varies in volume as the tendon assembly moves up and
6 down due to heave of the hull; and wherein the system further comprises:
7 a port in the chamber to draw in and expel sea water to dampen the up and down motion of the
8 engaging member; and
9 an adjustable valve over the port for adjusting a flow area through the port.

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11 6. The system according to claim 1, further comprising a plurality of internal risers, each having
12 a separate axis, the internal risers being located in the tendon assembly and extending to the hull
13 for transporting petroleum products between the hull and the sea floor.

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15 7. The system according to claim 1, further comprising :
16 a plurality of flowlines adapted to be coupled to well equipment on the sea floor and extending to
17 the counterweight; and
18 a plurality of internal risers joined to upper ends of the flowlines at the counterweight and
19 extending through the tendon assembly to the hull, each of the internal risers having a separate
20 axis.

1 8. The system according to claim 1, further comprising at least one external riser extending
2 alongside the tendon assembly to the hull, the external riser adapted to be connected to a subsea
3 wellhead at the sea floor.

4
5 9. The system according to claim 1, further comprising an anti-rotation device between the
6 engaging member and the upper end of the anchor member for preventing rotation of the
7 engaging member relative to the anchor member.

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9 10. The system according to claim 1, further comprising a plurality of external risers, each of the
10 external risers adapted to be connected to a subsea wellhead at the sea floor, at least some of the
11 external risers engaging the counterweight to prevent rotation of the counterweight relative to the
12 anchor member.

13
14 11. The system according to claim 1, wherein the upper end of the tendon assembly is
15 cylindrical, and the system further comprises:
16 a cylindrical receptacle in the hull that receives an upper end of the tendon assembly, the
17 receptacle having a plurality of circumferentially spaced lugs;
18 a plurality of keys spaced around the upper end of the tendon assembly for engaging the lugs;
19 and
20 the tendon assembly secures to the receptacle by relative rotation between the tendon assembly
21 and the receptacle until the keys engage the lugs.

12. The system according to claim 1, wherein the anchor member comprises a tubular piling,
and the engaging member comprises a sleeve that slides over the piling.

13. The system according to claim 1, wherein the anchor member comprises a caisson, and the
engaging member comprises a piston member that locates within the caisson.

14. The system according to claim 1, wherein the tendon assembly comprises:
an upper riser section extending downward from the hull and a lower tendon section extending
downward from the upper riser section, the upper riser section being larger in diameter and
shorter in length than the lower tendon section; and the system further comprises:
an upper weight secured to a lower end of the upper riser section.

15. The system according to claim 1, wherein the tendon assembly comprises:
an upper riser section extending downward from the hull and a lower tendon section extending
downward from the upper riser section, the upper riser section being larger in diameter and
shorter in length than the lower tendon section; and wherein the system further comprises:
a shoulder in a lower end of the upper riser section for supporting an upper end of the lower
tendon section; and
a hanger on an upper end of the lower tendon section for landing on the shoulder, the lower
tendon section being run through the upper riser section.

16. The system according to claim 1, wherein the tendon assembly comprises:

1 an upper riser section extending downward from the hull and a lower tendon section extending
2 downward from the upper riser section, the upper riser section being larger in diameter and
3 shorter in length than the lower tendon section; and wherein the system further comprises:
4 an upper weight at a lower end of the upper riser section; and
5 a top connector on the upper weight for securing an upper end of the lower tendon section, the
6 upper end of the lower tendon section having a separate axis from an axis of the upper riser
7 section.

8
9 17. The system according to claim 1, wherein the tendon assembly comprises:

10 an upper riser section extending downward from the hull and a plurality of lower tendons
11 extending downward from the upper riser section, the upper riser section being larger in diameter
12 and shorter in length than any of the lower tendons; and wherein the system further comprises:
13 an upper weight at a lower end of the upper riser section; and
14 a plurality of top connectors on the upper weight, each securing an upper end of one of the lower
15 tendons to the upper riser section.

16
17 18. An offshore system for petroleum production, comprising:

18 a buoyant hull;
19 a tendon assembly cooperatively engaged with the hull;
20 a counterweight secured to a lower end of the tendon assembly to provide tension to the tendon
21 assembly;
22 a piling embedded in a sea floor and having an upper end protruding above the sea floor; and

1 a socket at the counterweight that telescopingly slides over the upper end of the piling, defining a
2 dampening chamber that varies in volume as the counterweight moves up and down due to heave
3 of the hull.

4
5 19. The system according to claim 18, further comprising a port in the chamber for ingress and
6 egress of sea water.

7
8 20. The system according to claim 18, further comprising:
9 a port in the chamber for ingress and egress of sea water; and
10 a valve mounted to the port for selectively adjusting a flow area of the port.

11
12 21. The system according to claim 20, further comprising a check valve that provides a greater
13 flow area for the egress of sea water from the chamber during downward movement of the
14 engaging member than a flow area for the ingress of sea water during upward movement of the
15 engaging member.

16
17 22. The system according to claim 18, further comprising a plurality of internal risers, each
18 having a separate axis, the internal risers being located in the tendon assembly and extending to
19 the hull for transporting petroleum products between the hull and equipment on the sea floor.

20
21 23. The system according to claim 18, further comprising an anti-rotation member between the
22 piling and the counterweight for preventing rotation of the tendon assembly relative to the piling.

1 24. The system according to claim 18, further comprising :

2 a plurality of flowlines adapted to be coupled to well equipment on the sea floor and extending to
3 the counterweight; and

4 a plurality of internal risers joined to upper ends of the flowlines at the counterweight and
5 extending through the tendon assembly to the hull, each of the internal risers having a separate
6 axis.

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8 25. The system according to claim 18, further comprising a plurality of external risers extending
9 alongside the tendon assembly, each of the external risers adapted to be connected to a subsea
10 wellhead at the sea floor, at least one of the external risers extending through a passage provided
11 by the counterweight so as to prevent rotation of the counterweight relative to the piling.

12
13 26. The system according to claim 18, wherein the upper end of the tendon assembly is
14 cylindrical and the system further comprises:
15 a cylindrical receptacle in the hull that receives an upper end of the tendon assembly, the
16 receptacle having a plurality of circumferentially spaced lugs;
17 a plurality of keys spaced around the upper end of the tendon assembly for engaging the lugs;
18 and
19 the tendon assembly secures to the receptacle by relative rotation between the tendon assembly
20 and the receptacle until the keys engage the lugs.

21
22 27. The system according to claim 18, wherein the tendon assembly comprises:

1 an upper riser section extending downward from the hull and a lower tendon section extending
2 downward from the upper riser section, the upper riser section being larger in diameter and
3 shorter in length than the lower tendon section; and the system further comprises:
4 an upper weight secured to a lower end of the upper riser section.

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6 28. The system according to claim 18, wherein the tendon assembly comprises:

7 an upper riser section extending downward from the hull and a lower tendon section extending
8 downward from the upper riser section, the upper riser section being larger in diameter and
9 shorter in length than the lower tendon section; and wherein the system further comprises:
10 an upper weight at a lower end of the upper riser section;
11 a shoulder in the lower end of the upper riser section; and
12 a hanger on an upper end of the lower tendon section for landing on the shoulder, the lower
13 tendon section being run through the upper riser section.

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15 29. The system according to claim 18, wherein the tendon assembly comprises:

16 an upper riser section extending downward from the hull and a lower tendon section extending
17 downward from the upper riser section, the upper riser section being larger in diameter and
18 shorter in length than the lower tendon section; and wherein the system further comprises:
19 an upper weight at a lower end of the upper riser section; and
20 a top connector on the upper weight for securing an upper end of the lower tendon section, the
21 upper end of the lower tendon section having a separate axis from an axis of the upper riser
22 section.

1 30. The system according to claim 18, wherein the tendon assembly comprises:
2 an upper riser section extending downward from the hull and a plurality of spaced apart, parallel
3 lower tendons extending downward from the upper riser section, the upper riser section being
4 larger in diameter and shorter in length than any of the lower tendons; and wherein the system
5 further comprises:
6 an upper weight at a lower end of the upper riser section; and
7 a plurality of top connectors on the upper weight, each top connector securing an upper end of
8 one of the lower tendons.

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10 31. An offshore system for petroleum production, comprising:
11 a buoyant hull;
12 a tendon assembly cooperatively engaged with the hull;
13 a counterweight secured to a lower end of the tendon assembly to provide tension to the tendon
14 assembly,
15 a caisson on a sea floor; and
16 a piston mounted to the tendon assembly and located within the caisson, the piston being
17 upwardly and downwardly movable relative to the caisson due to heave of the hull; and
18 at least one passage extending from below to above the piston to allow sea water to flow past the
19 piston as the piston moves relative to the caisson for dampening the upward and downward
20 movement.

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22 32. The system according to claim 31, wherein the passage comprises a port through the piston.
23

33. An offshore system for petroleum production, comprising:

- a buoyant hull;
- an upper riser section extending downward from the hull;
- an upper weight located at a lower end of the upper riser section to apply tension to the upper riser section;
- at least one lower tendon section having an upper end coupled to the lower end of the upper riser section, the lower tendon section being substantially longer than the upper riser section and smaller in diameter;
- a counterweight secured to a lower end of the tendon assembly to provide tension to the tendon assembly;
- a piling embedded in a sea floor; and
- a socket at the counterweight that slides over the upper end of the piling and moves up and down relative to the piling due to heave of the hull.

34. The system according to claim 33, wherein the piling and the socket define a chamber that varies in volume as the socket moves up and down, the chamber having a port to draw in and expel sea water to dampen the up and down movement of the socket.

35. The system according to claim 33, further comprising:

- a shoulder in the lower end of the upper riser section; and
- a hanger on the upper end of the lower tendon section for landing on the shoulder, the lower tendon section being run through the upper riser section.

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2 36. The system according to claim 33, wherein said at least one lower tendon section comprises a
3 plurality of lower tendon sections, and wherein the system further comprises:
4 a plurality of top connectors on the upper weight for securing the upper ends of the lower tendon
5 sections.

6
7 37. A method for mooring a buoyant offshore hull, comprising:

8 (a) embedding an anchor member in a sea floor;

9 (b) telescopingly engaging a lower end of a tendon assembly with the anchor member, thereby
10 preventing lateral movement of the lower end of the tendon assembly but allowing upward and
11 downward movement of the tendon assembly;

12 (c) providing a counterweight at the lower end of a tendon assembly, thereby applying tension to
13 the tendon assembly; and

14 (d) securing an upper end of the tendon assembly to the hull.
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16 38. The method according to claim 37, wherein step (c) comprises suspending a container at the
17 lower end of the tendon assembly and pumping a heavy liquid material down the tendon
18 assembly to the container.
19

20 39. The method according to claim 37, further comprising preventing rotation of the tendon
21 assembly relative to the anchor member.
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23 40. The method according to claim 37, further comprising:

1 providing a chamber between the piling and the tendon assembly; and

2 causing sea water to be drawn into the chamber as the tendon assembly moves upward relative to

3 the anchor member, and expelling sea water from the chamber as the tendon assembly moves

4 downward relative to the anchor member.

5
6 41. The method according to claim 40, wherein the sea water is drawn into the chamber through

7 a port, and wherein the method further comprises:

8 varying a flow area of the port to change dampening caused by the drawing in and expelling of

9 sea water.

10
11 42. The method according to claim 37, further comprising:

12 providing a chamber between the piling and the tendon assembly, the chamber having a first

13 flow area for expelling sea water from the chamber and a smaller second flow area for drawing

14 in sea water into the chamber;

15 causing sea water to be drawn into the chamber through the first flow area as the tendon

16 assembly moves upward relative to the anchor member, and expelling sea water from the

17 chamber through the second flow area as the tendon assembly moves downward relative to the

18 anchor member.

19
20 43. The method according to claim 37, wherein step (d) comprises:

21 positioning the upper end of the tendon assembly below sea level;

22 floating the hull over the upper end of the tendon assembly; then

23 ballasting the hull until it lowers into engagement with the upper end of the tendon assembly.

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2 44. The method according to claim 37, wherein steps (b) and (d) comprises:
3 providing the tendon assembly with an upper riser section and a lower tendon section, securing
4 the upper riser section to the hull, then lowering the lower tendon section through the upper riser
5 section.

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7 45. The method according to claim 37, further comprising after step (d) flowing petroleum
8 products through the tendon assembly between equipment at the sea floor and on the hull.

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